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SITE INVESTIGATION SERVICES
LIMITED

677 CROWN DRIVE PETERBOROUGH, ONT. PHONE 743-6850

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REPORT ON SAMPLING TECHNIQUES

NORDIC MINES TAILINGS DEPOSIT

ELLIOT LAKE, ONTARIO

TO: T.P. LIM
DEPARTMENT OF ENERGY MINES & RESOURCES
ELLIOT LAKE LABORATORY,
CANMET, MRL,
P.O. BOX 100,
ELLIOT LAKE, ONTARIO. P5A 2J6

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CONTINUOUS CORE SAMPLING, NORDIC MINES TAILINGS DEPOSIT

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NATURE OF THE MATERIAL

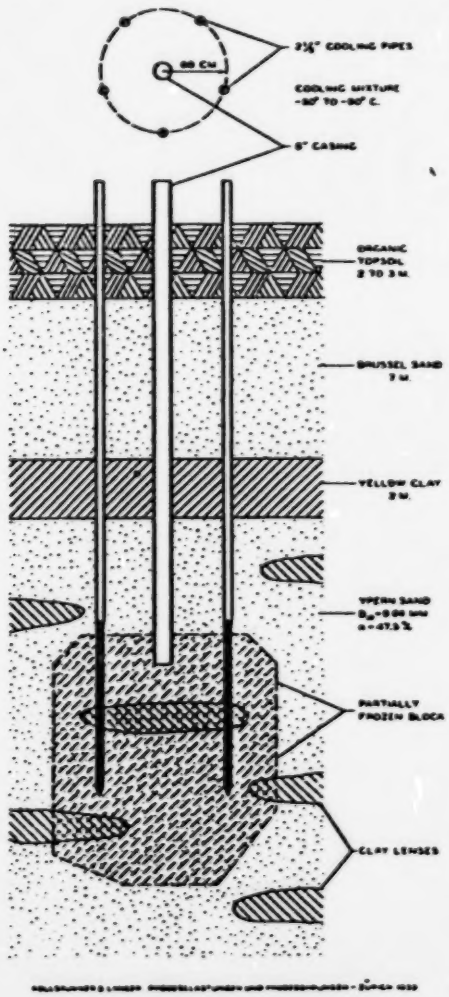
The tailings material consists mainly of very fine sand, silt and some clay-sized particles. The material was deposited in a very loose state and, except for a somewhat compacted crustal zone near the surface, remains in a relatively loose state. The porosity of the material (ratio of void volume to total volume of voids and solids) is estimated to range from 47% to 52% in the loose state to about 23% to 29% in a compact or dense state. The permeability coefficient of the materials sampled is estimated to range from 10^{-3} to 10^{-5} cm/sec., with 10^{-4} cm/sec. being a reasonable average.

Above the ground water table the tailings are moist, but not saturated, except in the capillary zone just above the water table. In the capillary zone and below the water table the soils are saturated.

SAMPLING PROBLEMS

The materials described above are some of the most difficult for the geotechnical engineer to sample. Because of their very loose condition they tend to compact when disturbed, even by very small forces. The pushing, vibration and cutting loads induced by the gentlest of sampling procedures will cause a decrease in volume of the sample due to reduction of the volume of voids.

The only positive way to obtain a structurally undisturbed sample of such materials is to solidify the material by impregnation of the voids with hardening chemicals or by freezing of the soil. A description of this method used by Langer and Kollbrunner in soils very similar to those at the Nordic site follows -



PARTIAL FREEZING BEFORE SAMPLING

FIG. 251

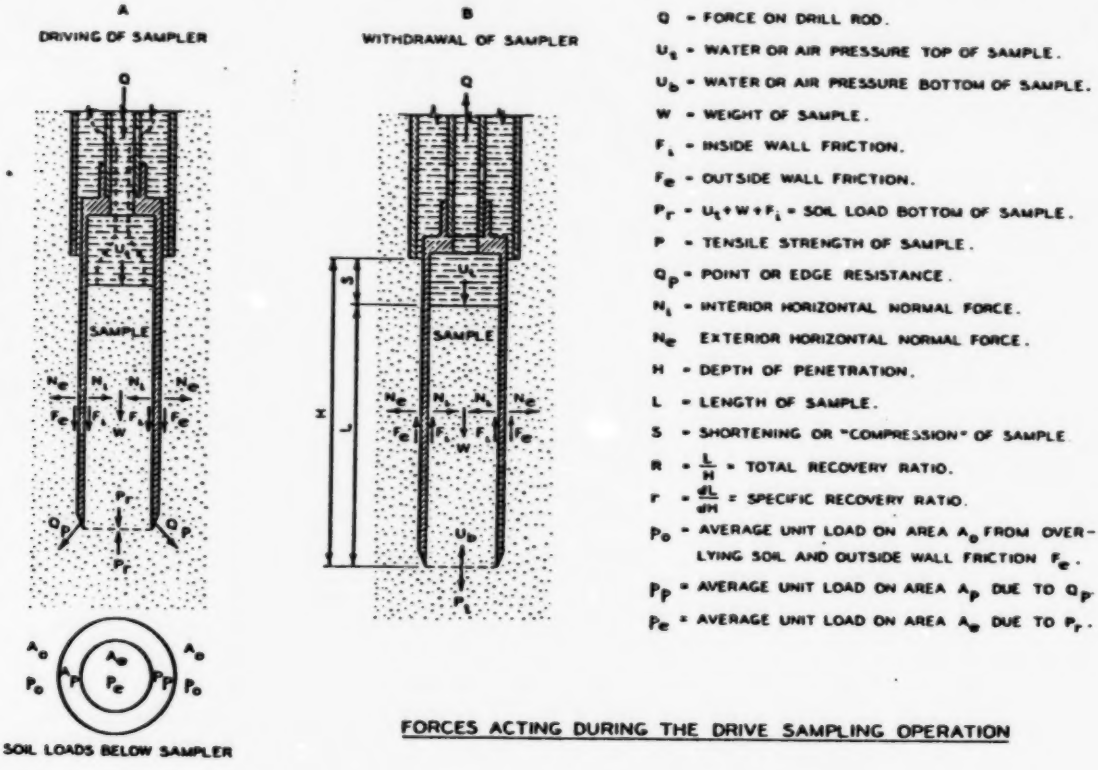
Partial or complete freezing of the soil before sampling presents fewer complications than impregnation and has been used in several instances. Langer and Kollbrunner (150, 225, 333) report successful application of partial freezing or undercooling in sampling of very loose sandy silt. Attempts to obtain samples of this soil without freezing were unsuccessful unless one of the scattered clay lenses shown in Fig. 251 was encountered at the end of a drive. Furthermore, the internal structure of the soil was so unstable that any displacement or vibration produced a considerable decrease in void ratio. The cooling was accomplished by driving five 2-1/2-in. pipes in a circle around the 6-in. boring and partially filling these pipes with a freezing mixture having a temperature of about -80°C. The freezing mixture was changed every 2 hours for a total period of about 12 hours. The temperature of the soil was thereby decreased and the viscosity of the pore water increased to such an extent that the soil acquired a consistency resembling that of a soft clay. The samples could then be obtained without material changes in void ratio and retained in a sampler similar to that shown in Fig. 197.

SAMPLING PROBLEMS (cont'd)

Since freezing and impregnation are not acceptable techniques for this particular tailings study, we are forced to use methods which will not cause structural disturbance of the material during sampling. The sampling methods used at the Nordic Mines site, have evolved from the experiences of Can Met, Waterloo University and ourselves. The particular problems at the Nordic Mines centre around the very loose, unconsolidated nature of the fine-grained tailings which makes them easily disturbed and the difficulty in retaining saturated samples of the material which tends to flow readily out of the bottom of sampling tubes. The latter problem was sometimes overcome, if a layer of peat existed below the sample location, by advancing the sample into the peat to form a bottom plug. We have also developed a thin wall sampler trap that closes off the end of the sampler when it is withdrawn. A third technique used at some stages of this project consisted of overdriving the relatively weak aluminum tubing into the dense stoney till soils below the tailings. The overdriving caused the end of the tube to collapse and thus contain the sample during withdrawal. To minimize the problem of disturbance (primarily by compaction in this case) a very thin-walled (0.05 ins.) aluminum tubing with a 3-inch O.D. was found to be reasonably effective. The area ratio (kerf ratio) of this tubing is about 0.07 which is much less than the 0.12 kerf ratio of a conventional 3-inch shelby tube normally used by geotechnical engineers for undisturbed sampling. Very long samples (up to 20 feet) have been recovered at the Nordic Mines deposit using the thin-walled aluminum tubing. Recovery ratios of 80% to 90% have been achieved. (Definitions of area ratios and recovery ratios as prepared by Hvorslev are noted at the end of this report).

METHOD OF ADVANCING SAMPLER

As indicated on the following sketch there are a number of forces which act on the sample during the sampling operation.



Q = FORCE ON DRILL ROD.
U_t = WATER OR AIR PRESSURE TOP OF SAMPLE.
U_b = WATER OR AIR PRESSURE BOTTOM OF SAMPLE.
W = WEIGHT OF SAMPLE.
F_i = INSIDE WALL FRICTION.
F_e = OUTSIDE WALL FRICTION.
$P_r = U_t + W + F_i$ = SOIL LOAD BOTTOM OF SAMPLE.
P = TENSILE STRENGTH OF SAMPLE.
Q_p = POINT OR EDGE RESISTANCE.
N_i = INTERIOR HORIZONTAL NORMAL FORCE.
N_e EXTERIOR HORIZONTAL NORMAL FORCE.
H = DEPTH OF PENETRATION.
L = LENGTH OF SAMPLE.
S = SHORTENING OR "COMPRESSION" OF SAMPLE
$R = \frac{L}{H}$ = TOTAL RECOVERY RATIO.
$r = \frac{dL}{dH}$ = SPECIFIC RECOVERY RATIO.
P_o = AVERAGE UNIT LOAD ON AREA A_o FROM OVERLYING SOIL AND OUTSIDE WALL FRICTION F_e.
P_p = AVERAGE UNIT LOAD ON AREA A_p DUE TO Q_p
P_e = AVERAGE UNIT LOAD ON AREA A_e DUE TO P_r.

FORCES ACTING DURING THE DRIVE SAMPLING OPERATION

The major forces which have to be contended with are those of friction drag (Fi) between the soil and sampler wall and the soil load (Pr) at the bottom of the sample. If the friction loads become too large there is a tendency to push soft material below the sample away from the sampler. Using straight pushing techniques did not seem to be effective at the Nordic site in the saturated zone, and I assume it was because of high friction drag.

METHOD OF ADVANCING SAMPLER (cont'd)

On the other hand, very light tapping with a conventional 140 lb. drop hammer using a 1 to 3 inch drop appeared to minimize the friction effect. I believe that the reason for this is that the vibration from the hammer blows caused some liquifacation of the soil along the sides of the sample tube which reduced the friction. For this reason, the tapping techniques worked best in wet soils.

ANALYSIS OF NORDIC SITE SAMPLING

A review of the samples obtained for this study reveals that total recovery ratios ranged from 91% to 100% which is considered very good for the materials involved. Since the porosity of the tailings is estimated to range from 50% in the loose state to 25% in the compact state, it is therefore possible to lose 25% of the sample volume due to compaction. Which is to say that a 40 cm long sample in-situ could become a 30 cm long sample after compaction even when all the material has been recovered. Such compaction in the saturated zone could occur only in relatively coarse sandy lenses from which pore water could readily flow. Since the tailings are quite silty in texture, this compaction effect would take place mainly in the dry or unsaturated zones and not in the saturated zone.

In order to achieve high recovery ratios in the upper unsaturated crustal zone, it was found most productive to shorten the sample interval to 6 inches. (Particularly since each sample jar could hold a 6-inch sample). The short samples were obtained by pushing the tube smoothly with the drill hydraulic feed rams. This procedure was used down to the saturated zone or to a depth of 9 feet in hole T_1 and 14 feet in hole T_2.

ANALYSIS OF NORDIC SITE SAMPLING (cont'd)

In the saturated zone, the core tubes were advanced by light tapping of the 140-lb safety hammer. The samples were retained in the tube, either by overdriving into the underlying till soils or by a thin-wall trap fitted to the end of the tube.

Details of the sampling operation and recovery are as follows:

(a) SAMPLE AREA T_1

DEPTH (Ft.)	DESCRIPTION	RECOVERY (%)
0 - 9	Pushed tube 6 inches for each 6-inch sample	100
9 - 11	Tapped tube with trap	91.7
10.5.- 30	Tapped tube without trap (No rec)	0
10.5 - 30	Tapped tube with trap (15.5' recovery) (10.5' - 20' full recovery) (20' - 30' ---50% loss due to compaction and displacement, material abandoned)	79.5
30 - 32	Tapped 20' tube to 32' (recovered 2' of organic clay silt and gravel till)	100
	(MOVED BOREHOLE 3 FEET AND RE-AUGERED TO 20')	
20 - 31	Tapped tube to 31' into till (11' recovery)	100

(b) SAMPLE AREA T_2

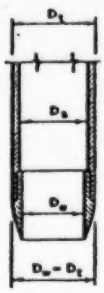
DEPTH (Ft.)	DESCRIPTION	RECOVERY (%)
0 - 14	Pushed tube 6 inches for each 6-inch sample (full recovery)	100
14 - 29	Tapped tube, without trap, into dense till (recovered 14')	93.3

In spite of the difficulties associated with sampling these sensitive tailings materials, a very high recovery ratio was achieved. The friendly cooperation of the CANMET staff contributed to that success.

Report prepared by

JOHN A. HAYES, B.Sc., D.I.C., P.Eng.,
Geotechnical Consultant for:

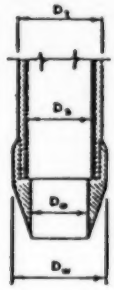
SITE INVESTIGATION SERVICES LIMITED

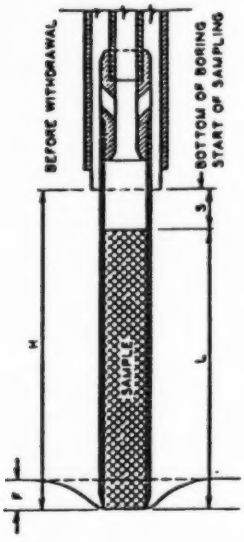


INSIDE CLEARANCE $C_i = \frac{D_s - D_o}{D_o}$ CONTROLS INSIDE FRICTION

OUTSIDE CLEARANCE $C_o = \frac{D_o - D_i}{D_i}$ CONTROLS OUTSIDE FRICTION

AREA OR KERF RATIO $C_a = \frac{D_o^2 - D_s^2}{D_o^2}$ $\frac{\text{VOLUME OF DISPLACED SOIL}}{\text{VOLUME OF SAMPLE}}$





H = DEPTH OF PENETRATION = DISTANCE ORIGINAL BOTTOM OF BORE HOLE TO CUTTING EDGE OF SAMPLER.

L = ORIGINAL LENGTH OF SAMPLE = DISTANCE TOP OF SAMPLE TO CUTTING EDGE OF SAMPLER BEFORE WITHDRAWAL.

L_g = GROSS LENGTH OF SAMPLE = DISTANCE TOP OF SAMPLE TO CUTTING EDGE OF SAMPLER AFTER WITHDRAWAL.

L_n = NET LENGTH OF SAMPLE = DISTANCE TOP TO BOTTOM OF SAMPLE AFTER TRIMMING FOR SEALING.

L_t = NET LENGTH OF SAMPLING TUBE = INSIDE DISTANCE FROM CUTTING EDGE TO SAMPLE HEAD.

L/H = TOTAL RECOVERY RATIO.

$\Delta L/\Delta H$ = SPECIFIC RECOVERY RATIO.

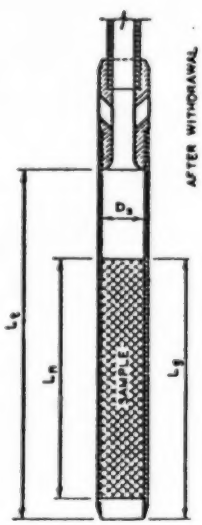
L_g/H = GROSS RECOVERY RATIO.

L_n/H = NET RECOVERY RATIO.

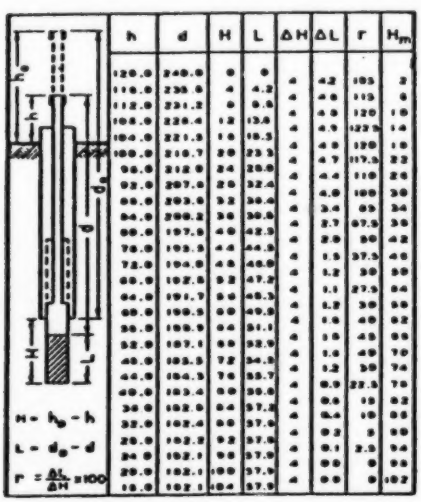
F = DEFLECTION OF SOIL AT CUTTING EDGE

$\frac{L}{H-F}$ = TRUE TOTAL RECOVERY RATIO

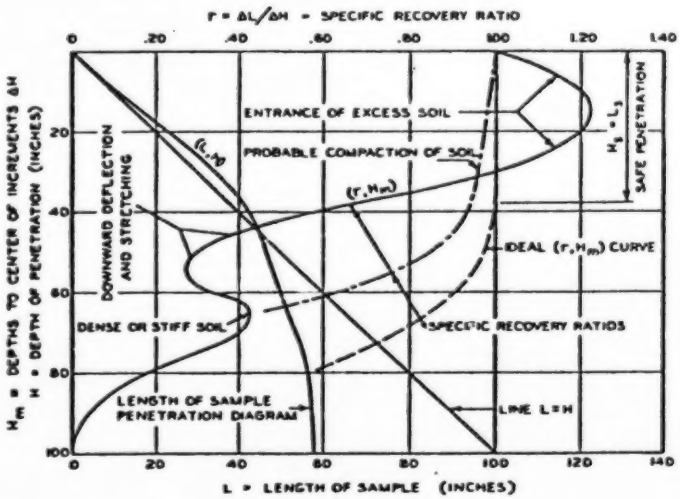
$H_s = L_s$ = SAFE PENETRATION OR SAFE LENGTH OF SAMPLE = MAXIMUM PENETRATION FOR WHICH $\Delta L = \Delta H$ AND $L = H$ CAN BE MAINTAINED = MAXIMUM LENGTH OF UNDISTURBED SAMPLE.



CHARACTERISTIC DIMENSIONS, MEASUREMENTS AND RATIOS IN DRIVE SAMPLING



h	d	H	L	ΔH	ΔL	r	H_m
120.0	240.0	0	0	Δ	4.2	105	2
116.0	236.0	4	4.2	Δ	4.6	115	6
112.0	231.2	8	8.8	Δ	4.8	120	10
108.0	226.4	12	13.6	Δ	4.9	122.5	14
104.0	221.5	16	18.5	Δ	4.8	120	18
100.0	216.7	20	23.3	Δ	4.7	117.5	22
96.0	212.0	24	28.0	Δ	4.4	110	26
92.0	207.6	28	32.4	Δ	4.0	100	30
88.0	203.6	32	36.4	Δ	3.4	85	34
84.0	200.2	36	39.8	Δ	2.7	67.5	38
80.0	197.5	40	42.5	Δ	2.0	50	42
76.0	195.5	44	44.5	Δ	1.5	37.5	46
72.0	194.0	48	46.0	Δ	1.2	30	50
68.0	192.8	52	47.2	Δ	1.1	27.5	54
64.0	191.7	56	48.3	Δ	1.2	30	58
60.0	190.5	60	49.5	Δ	1.8	45	62
56.0	189.9	64	51.1	Δ	1.6	40	66
52.0	187.1	68	52.9	Δ	1.8	45	70
48.0	185.5	72	54.5	Δ	1.6	40	74
44.0	184.3	76	55.7	Δ	1.2	30	78
40.0	183.4	80	56.6	Δ	0.9	22.5	82
36.0	182.8	84	57.2	Δ	0.6	15	86
32.0	182.4	88	57.6	Δ	0.4	10	90
28.0	182.2	92	57.8	Δ	0.2	5	94
24.0	182.1	96	57.9	Δ	0.1	2.5	94
20.0	182.1	100	57.9	Δ	0.0	0	98
16.0	182.1	104	57.9	Δ	0.0	0	102



TYPICAL RECOVERY RATIO CURVES

POOR

QUALITY

ORIGINAL